Species Richness and Habitat Associations of Non-flying Mammals in Gibraltar Range National Park

KARL VERNES, STUART GREEN, ALISON HOWES AND LINDA DUNN

School of Environmental Sciences and Natural Resources Management, Ecosystem Management, The University of New England, Armidale, NSW 2351.

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We surveyed mammals in Gibraltar Range National Park using a range of census methods between May 2003 and September 2005. Our primary survey techniques included 5780 trap nights and more than 40 km of walked spotlighting transects, and our observations, coupled with previously collected datasets, revealed the occurrence of 28 native species and six introduced species of non-flying mammal. To examine the importance of habitat heterogeneity in influencing this high mammal species richness, we surveyed mammals across a steep vegetation gradient from swamp, through two eucalypt forest types, to rainforest. The mammal community responded strongly to this gradient, with different suites of species favouring different parts of the gradient. We also attempted to describe the entire mammal community in one of these forest types, wet eucalypt forest, because we suspected it to be one of the more species-rich habitats in the park. The mammal community in this forest type was assessed on two 2.6-ha grids using Elliot and cage trapping (plus incidental observations), and comprised at least 12 species of non-flying native mammal. Brown antechinus (*Antechinus stuartii*), bush rats (*Rattus fuscipes*), and fawn-footed melomys (*Melomys cervinipes*) were the most abundant ground-dwelling mammals in this community.

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INTRODUCTION

Despite Gibraltar Range National Park being one of the oldest parks in New South Wales (reserved in 1963; NSW NPWS 2005), relatively little published information exists on the mammals in the park. Surveys by Osbourne and Marsala (1982) and Pulsford (1982) are summarised by Clancy (1999) who provided a list of 25 native and six introduced species for the park, but few other details about habitat associations or relative abundances. More recently, records of flora and fauna gathered over many decades by a number of government agencies in New South Wales have become available on a single web-accessible database (BioNet Database, 2005). Although this database has great utility in the generation of species lists for any given region, it provides no quantitative data on faunal abundances, and because contributions to the database can be made by any interested individual (through submissions to the NSW Department of Environment and Conservation Atlas), the veracity of some records is difficult to confirm.

One of us (Vernes) has begun a long-term study on the mammals of Gibraltar Range, particularly those species that consume and disperse the spores of hypogeous ectomycorrhizal fungi, otherwise known as 'truffles'. As a first step in understanding the mammal community structure and dynamics in the region, we have surveyed mammals at a range of sites in Gibraltar Range, and present these data here. In addition to providing a simple species list for the park, we have also attempted to summarise the broad habitat preferences of mammals that are present, and to show how habitat heterogeneity in the park leads to the structuring of distinct mammal communities.

MATERIALS AND METHODS

Study area

We undertook broad, observational surveys throughout Gibraltar Range National Park in

northeast New South Wales, but focused our trapping and spotlighting in the north-eastern section of the park and an adjacent area in the southern part of Washpool National Park (Fig. 1). This region of these adjacent parks includes the wetter forest types to be found in the area (including rainforest) and we expected mammal species richness to be highest here. The north-eastern region of the park is on the extreme eastern edge of the New England Tableland bioregion, and straddles the interface between the Tableland and the Great Escarpment, a part of the Great Dividing Range characterised by rugged topography and dramatic changes in elevation. The study region is characterised by high ridges and plateaus, with a mean elevation of 1000 m, although altitude in the park ranges from 200 m to 1175 m (NSW NPWS 2004). The regional topography and relatively high altitude contributes to a high local rainfall of around 2000 mm annually at the highest elevation around the Great Escarpment (NSW NPWS 2004), although rainfall decreases rapidly westward away from the scarp to be around 1100 mm annually in the drier parts of the park (NSW NPWS 2004). Winters are usually dry and cold, with average winter daytime temperatures of 13°C (NSW NPWS 2004). Most rains occur in the months of November to April, with average daytime temperatures in summer of around 25°C (NSW NPWS 2004).

A diversity of vegetation types is present in the park, and they occur in a tortuous mosaic that reflects combinations of soil type, a complex underlying geology, local rainfall and fire history (NSW NPWS 2004). Over distances of a few hundred metres vegetation can grade from open sedge swamps and wooded heaths to tall wet forest and rainforest, and the ecotones between these habitats are often sharp. The dominant vegetation type can broadly be described as eucalypt woodland with a heath-dominated understorey; although considerable tracts of open sedge swamp, tall open eucalypt forest and rainforest are present in the landscape. The importance of the more mesic habitats in Gibraltar Range and the adjoining Washpool National Park was recognised by their listing as part of the Central Eastern Rainforest Reserves of Australia (CERRA) World Heritage Area. Sheringham and Hunter (2002) provide a detailed description of vegetation in these parks.

The study consisted of three elements. The first comprised a survey of mammal species present within Gibraltar Range National Park identified through observation during spotlighting and other visual searches, from their scats and diggings, and by examination of road kills. The second element of the study was concerned with understanding the changes to the small mammal community over a continuous ecological gradient spanning a range of locally common vegetation types found in the north-eastern part of the park. The third element focused on the small mammal community in one of these vegetation types, wet open eucalypt forest, in order to understand more fully the structure of the small mammal community present. This element of the study is ongoing, and here we present the first year of data.

Mammal survey of Gibraltar Range

We conducted spotlighting surveys along ten transects ranging in length from 500 m to 1500 m in various regions of the park (see Fig. 1a) between May 2003 and September 2005. These transects were traversed on foot with 1–3 operators using 30 W spotlights, beginning at least one hour after dusk. Each transect was traversed between 1 and 3 times during the study, and all observations included exact locations of mammals and dates and times, recorded using a handheld GPS (Garmin GPS72). Whenever we encountered other signs of mammals in the park (scats, calls, diggings etc), or when mammals were seen at any time during the study, we also recorded the exact location of the observation, date, and time of day using a GPS. We also trapped ground-dwelling mammals in selected areas of the park (see following sections, and Fig. 1b). To augment our species list, we also drew upon data gathered by government agencies in Gibraltar Range National Park, and lodged with the BioNet Database (2005). This database is a compilation of all records from NSW State Forests, the NSW Department of Environment and Conservation, and the Australian Museum.

The mammal community along the swamp-to-rainforest gradient

We chose a site where vegetation associations graded from open sedge swamp, and graded into dry open eucalypt woodland with a heath understorey, then into wet open eucalypt forest with a fern understorey, and finally into rainforest (Fig. 1b). The ecotonal boundary between each habitat was sharp, being no greater than 25 m wide. We sampled mammals across the habitat gradient using four trapping and spotlighting transects (T1–T4; Fig. 1b) arranged so that each transect traversed each habitat and the intervening ecotones. A trapping cluster of nine Elliot traps arranged in a 3x3 grid with 20-m spacings was positioned along each transect in each habitat as well as on the ecotone between habitats (Fig. 1b) for a total of seven clusters (63 traps) per transect. The distance between each cluster was variable,

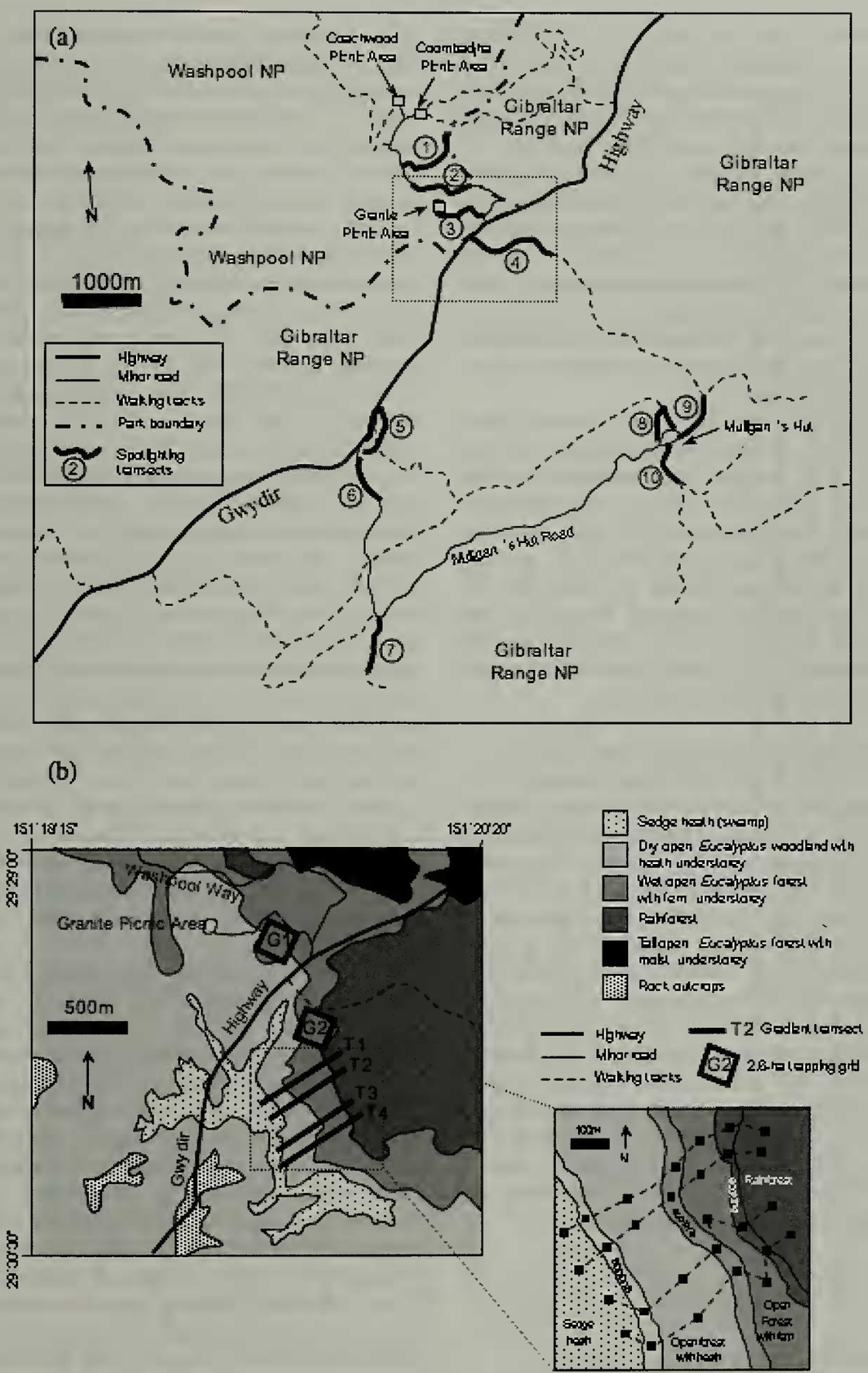

Figure 1. (a) Map of study area showing major roads and tracks, and location of spotlighting transects. (b) Detailed map of main study area (outlined by the box enclosed by a dotted line in Fig. 1a) showing major vegetation types, trapping grids, gradient transects. Inset shows the detail of transects that traversed the swamp–dry open woodland–wet open forest–rainforest gradient, and the intervening ecotones.

and depended upon the width of the habitat type; however, all trapping clusters were at least 100 m apart. Each transect was trapped for 3 nights per field trip, with field trips undertaken in November 2003 and February, March and April 2004. There were 756 trap nights per field trip, totalling 3024 trap nights for this part of the study. Each time a small mammal was captured during the study, we identified it to species, and collected data on sex, reproductive condition and body weight. A numbering system using an ear punch was employed to identify individuals over the duration of the study. Scat samples from all captured mammals were also collected for analysis of diet (to be reported elsewhere).

During November 2003, and February, March and April 2004, we also spotlighted each of the four transects that traversed the swamp-to-rainforest gradient (T1–T4; Fig. 1) twice, on different nights. Spotlighting began one hour after dusk, using two observers, each using a handheld 30 W spotlight. When an animal was sighted, we noted our own position with a GPS, estimated the distance and recorded the compass bearing to the sighted animal, thereby allowing us to later determine where the animal was in relation to habitat type.

Mammal community of the wet open-forest

Two 160x160 m (2.6-ha) trapping grids in wet open eucalypt forest were sampled for small mammals in April, June, August and September 2004. Each of these grids (G1 and G2; Fig. 1b) had a 9x9 grid of Type A Elliot traps spaced 20 m apart, with a 5x5 grid of larger cage traps spaced 40 m apart superimposed upon it. These grids were trapped for 2 – 4 nights per sampling period, yielding a total of 2106 Elliot trap nights and 650 cage trap nights. We selected this forest type based upon our previous survey work that identified this habitat as supporting a high diversity of mammals. We conservatively estimated relative density of trapped mammals on these grids as mean minimum numbers of animals known-to-be-alive (KTBA), although future work at this site aims to calculate more robust estimates of population size and density for all trappable mammals.

RESULTS

Mammals detected in the study region

We detected 11 mammal species across our ten spotlighting transects (Table 1). Amongst the seven arboreal species seen, the greater glider (*Petauroides volans*) was the most common, being detected at a rate of up to 9 animals per km of transect (Table 1). The common ringtail possum (*Pseudocheirus peregrinus*) was also regularly encountered (up to 9 animals per km; Table 1). The mountain brushtail possum (*Trichosurus caninus*) was often seen on transects that traversed rainforest, and we also recorded the presence of the common brushtail possum (*Trichosurus vulpecula*) in eucalypt forest, but this species appears to be considerably less common than *T. caninus*. We made three observations of koalas (*Phascolarctos cinereus*) in the wetter tall open forest along Washpool Way and Cedar Track (Fig. 1a). These records are all within Washpool National Park, but one of them was 200 m west of the Gibraltar Range park boundary (near that end of Cedar Track), and we have included it in our species list because the Sydney blue gum (*E. saligna*) habitat it was seen in continues east into the park, and we suspect the koala population does too. We also recorded three macropods on these spotlight surveys, the swamp wallaby (*Wallabia bicolor*), the red-necked pademelon (*Thylogale thetis*), and the parma wallaby (*Macropus parma*). The latter is listed as vulnerable in NSW, but appears to be locally common in the Mulligan's Hut area, where most of our sightings were made. Additionally, parma wallabies have been sighted at the Coachwood Picnic Area and along the Anvil Rock track by park staff (Kate Harrison, pers. comm.), and we also saw one during a vehicle spotlighting transect along the Raspberry Lookout road, near the western boundary of the park. Additional species not detected by spotlight were encountered during our mammal trapping (see Table 2), and these data will be discussed in the following sections.

We made incidental observations of other mammals in the region (see Table 2), some of which were not detected at any of our trapping and spotlighting sites. A macropod that we did not detect during spotlighting, the red-necked wallaby (*Macropus rufogriseus*), was regularly seen by us during daylight in the eucalypt woodlands and forests, and appears to be common and widespread. Furthermore, although we encountered swamp wallabies only once while spotlighting, evidence of them in the form of scats was ubiquitous throughout the study area, with the exception of rainforest. Dingo (*Canis lupus dingo*) scats are common along all roads and tracks in the park, and we recorded a road-kill dingo on the Gwydir Highway near the junction of the North West Fire Trail. We saw spotted-tail quoll (*Dasyurus maculatus*) scats in the wet forest areas too, but less commonly. Additionally, the northern brown bandicoot (*Isoodon macrourus*), rufous bettong (*Aepyprymnus rufescens*), brush-tailed rock wallaby

Transect Number	Name	Forest description	No. times surveyed	Transect length (m)	Numbers of animals seen per km										
					PN	PV	PP	PB	PC	TV	TC	AP	TT	MP	WB
1	Cedar Track (WNP)	Tall wet forest, grading to rainforest towards end	3	1000	0.3	3.3	4.0	0.3	0.7		2.7				
2	Washpool Way (WNP)	Tall wet eucalypt forest	3	1000		8.7		0.3	0.7		0.3				
3	Granite Road (WNP)	Open eucalypt woodland	1	800		7.5									
4	Washpool Walk	eucalypt forest that quickly grades to rainforest	3	500		3.3	8.7	0.7		0.7					
5	Headquarters Track	Open eucalyptwoodland	1	1500		4.0	0.7								
6	Mulligan's Drive	Open eucalypt woodland	1	700		1.4									
7	Anvil Rock Track	Open eucalyptwoodland	2	600		9.2		1.7				0.8			
8	Mulligan's Circuit	Open eucalypt woodland	2	500		8.0	1.0							6.0	
9	The Needles Track	eucalypt woodland, grading to rainforest	4	700	0.7	6.1	2.9	0.4							
10	Dandahra Falls Track	Open eucalypt woodland, grading to rainforest	5	700		7.1	2.9	0.6			1.1		0.9	1.7	0.3

Table 1. Species of mammal seen on spotlighting transects conducted in Gibraltar Range National Park and an adjacent section of Washpool National Park (WNP) between May 2003 and September 2005. Transect numbers correspond to those shown on Fig. 1(a). Relative estimates of abundance are presented as numbers of animals seen per km of spotlighting transect. PN = *Perameles nasuta*, PV = *Petauroides volans*; PP = *Pseudocheirus peregrinus*; PB = *Petaurus breviceps*; PC = *Phascolarctos cinereus*; TV = *Trichosurus vulpecula*; TC = *Trichosurus caninus*; AP = *Acrobates pygmaeus*; TT = *Thylogale thetis*; MP = *Macropus parma*; WB = *Wallabia bicolor.*

Table 2. Species of mammal detected in the study area at Gibraltar Range and Washpool National Parks, and their habitat associations. In each case, the method we primarily used to detect the presence of these species is listed. Species that were not detected during this study, but that are recorded as being present according to the BioNet Database (2005) are also recorded.

Common and Scientific Name	Detection Method
PROTOTHERIA (Monotremes)	
Family Tachyglossidae	
Short-beaked Echidna, *Tachyglossus aculeatus*	Diggings, seen
Family Ornithorhynchidae	
Platypus, *Ornithorhynchus anatinus*	Seen*
METATHERIA (Marsupials)	
Family Dasyuridae	
Spotted-tailed Quoll, *Dasyurus maculatus*[1]	Scat
Brown Antechinus, *Antechinus stuartii*	Trap
Family Peramelidae	
Northern Brown Bandicoot, *Isoodon macrourus*	BioNet
Long-nosed Bandicoot, *Perameles nasuta*	Trap, spotlight, scat
Family Burramyidae	
Eastern Pygmy-possum, *Cercartetus nanus*[1]	Trap
Family Acrobatidae	
Feathertail Glider, *Acrobates pygmaeus*	Spotlighting
Family Petauridae	
Sugar Glider, *Petaurus breviceps*	Spotlight, calls
Yellow-bellied Glider, *Petaurus australis*[1]	BioNet
Greater Glider, *Petauroides volans*	Spotlight
Family Pseudocheiridae	
Common Ringtail Possum, *Pseudocheirus peregrinus*	Spotlight
Family Phalangeridae	
Mountain Brushtail Possum, *Trichosurus caninus*	Trap, spotlight, scats
Common Brushtail Possum, *Trichosurus vulpecula*	Spotlight
Family Phascolarctidae	
Koala, *Phascolarctos cinereus*[1]	Spotlight
Family Potoroidae	
Rufous Bettong, *Aepyprymnus rufescens*[1]	BioNet
Long-nosed Potoroo, *Potorous tridactylus*[1]	Trap
Family Macropodidae	
Parma Wallaby, *Macropus parma*[1]	Spotlight, stag-watch
Red-necked Wallaby, *Macropus rufogriseus*	Scat, seen, road-kill
Brush-tailed Rock Wallaby, *Petrogale penicillata*[2]	BioNet
Red-legged Pademelon, *Thylogale stigmatica*[1]	BioNet, road-kill^
Red-necked Pademelon, *Thylogale thetis*	Spotlight, heard, scats
Swamp Wallaby, *Wallabia bicolor*	Scat, seen, spotlight

TABLE 2 CONTINUED

Common and Scientific name	Detection method
EUTHERIA ('Placental' Mammals)	
Family Muridae	
New Holland Mouse, *Pseudomys novaehollandiae*	Trap
Fawn-footed Melomys, *Melomys cervinipes*	Trap
House Mouse, *Mus musculus*[3]	Trap
Bush Rat, *Rattus fuscipes*	Trap
Swamp Rat, *Rattus lutreolus*	Trap
Black rat, *Rattus rattus*[3]	Clancy (1999)
Family Canidae	
Dingo, *Canis lupus dingo*	Scat, road-kill
European fox, *Vulpes vulpes*[3]	BioNet
Family Felidae	
Feral Cat, *Felis catus*[3]	Seen
Family Leporidae	
European rabbit, *Oryctolagus cuniculus*[3]	Seen
Family Suidae	
Feral Pig, *Sus scrofa*[3]	Diggings

1Listed as 'Vulnerable' in NSW
2Listed as 'Endangered' in NSW
3Introduced species
* K. Harrison (Park Ranger), personal communication
^ R. Goldingay (Southern Cross University), personal communication

(*Petrogale penicillata*), red-legged pademelon (*T. stigmatica*), feathertail glider (*Acrobates pygmaeus*), and yellow-bellied glider (*Petaurus australis*) have been recorded within our study area by others (BioNet Database, 2005).

Amongst introduced species, cats (*Felis catus*) and foxes (*Vulpes vulpes*) have been recorded in the park (BioNet Database 2005) and we have seen a rabbit (*Oryctolagus cuniculus*) in the Mulligan's Hut area. Feral pigs (*Sus scrofa*) have not been previously reported from the park, but we have noted diggings characteristic of pigs on the edges of swamps along Mulligan's Drive, but their presence needs to be verified with a sighting.

In all, our work in Gibraltar Range National Park in 2003 and 2004, coupled with data gathered from the BioNet Database, indicates the presence of 28 native and six introduced species of non-flying mammal (Table 2).

The mammal community along the swamp-to-rainforest gradient

Seven species of small mammal were detected in our traps across the habitat gradient (Sites T1–T4): four species of native rodent (bush rat *Rattus fuscipes*, swamp rat *R. lutreolus*, fawn-footed melomys *Melomys cervinipes*, and New Holland mouse *Pseudomys novaehollandiae*), the introduced house mouse (*Mus musculus*), the brown antechinus (*Antechinus stuartii*) and the eastern pygmy possum (*Cercartetus nanus*). Spotlighting yielded a further four species: the greater glider, common ringtail possum, sugar glider (*Petaurus breviceps*), and swamp wallaby.

The small mammal community changed markedly across the habitat gradient spanning swamp to rainforest (Fig. 2), despite this representing a distance of only about 700 m. Amongst small trappable mammals, several patterns in distribution emerged. *R. fuscipes* and *M. cervinipes* changed significantly in abundance (KTBA) between habitats ($P = 0.004$ and $P = 0.001$ respectively; Kruskal-Wallis Nonparametric ANOVA), with abundance increasing from the dry eucalypt woodland and the wet eucalypt forest, peaking on the open forest/rainforest ecotone, before declining inside the rainforest (Fig. 2a). *P. novaehollandiae* and *M. musculus* abundances were greatest on the ecotone between swamp and open woodland, declining either side of this region (Fig. 2b), significantly for *P. novaehollandiae* ($P = 0.001$; Kruskal-Wallis Nonparametric ANOVA with Dunn's Multiple Comparison Test), but the few captures of *M. musculus* precluded statistical comparisons.

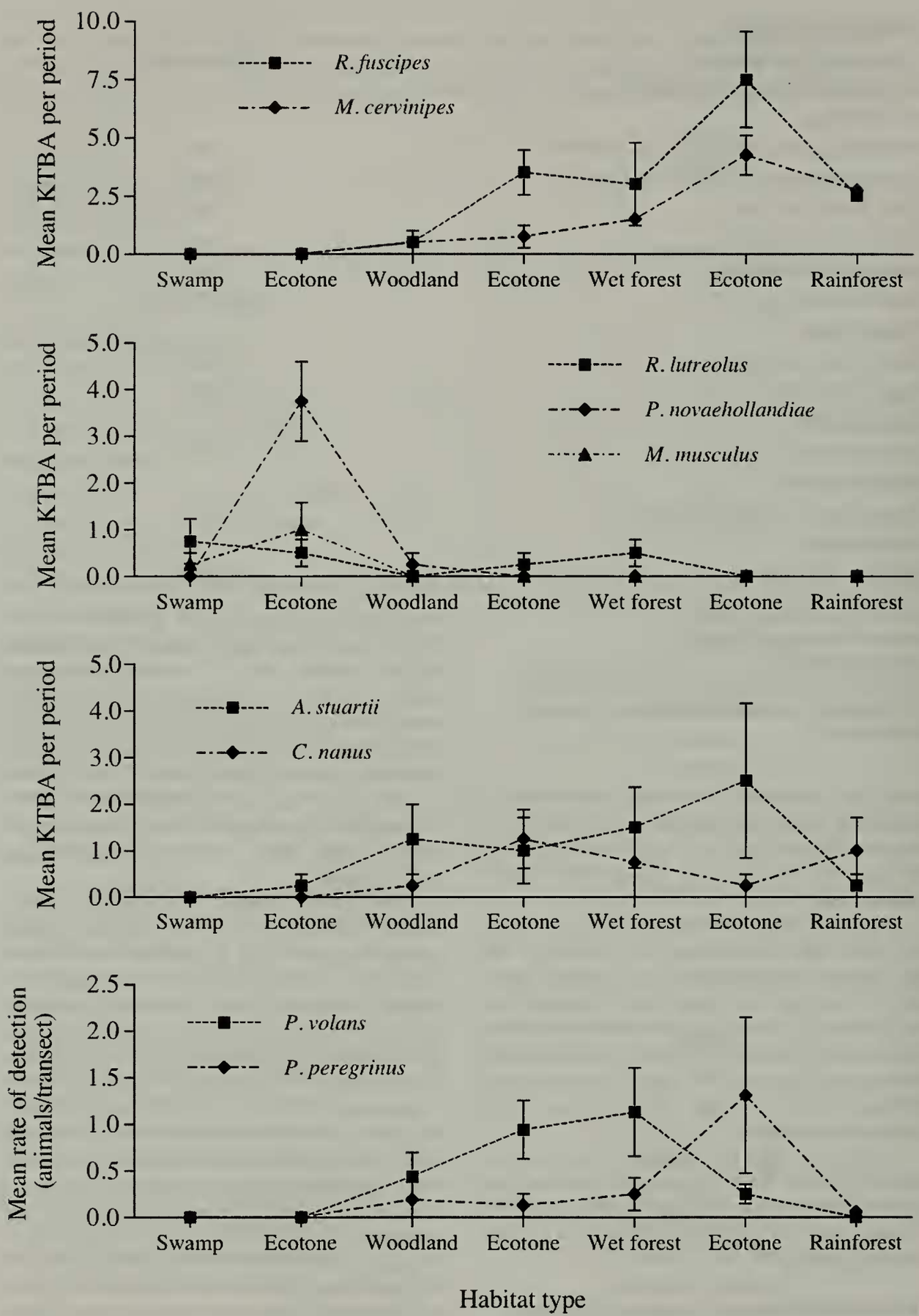

Figure 2. Changes in the mammal community across the gradient from swamp to rainforest, for the species detected in traps (Figs a-c) and by spotlighting (Fig. 2d).

Likewise, our few captures of *R. lutreolus* suggest that this species may also be associated with the swamp/open forest ecotone (Fig. 2b). *C. nanus* was captured in small numbers from rainforest to dry open eucalypt forest (Fig. 2c), but again, too sparsely to allow statistical analysis. *A. stuartii* was captured across the gradient from dry open woodland to rainforest, and no significant differences in abundance were detected (Fig. 2c; P > 0.3, Kruskal-Wallis Nonparametric ANOVA).

The two arboreal species that we sighted regularly (*P. volans* and *P. peregrinus*) during spotlighting along gradient transects (T1 – T4) also showed distinct habitat association. *P. volans* was seen in all eucalypt-dominated habitats and ecotones, but was significantly more common in the wet eucalypt forest and the wet forest/dry woodland ecotone (Fig. 2d; $P = 0.004$, Kruskal-Wallis Nonparametric ANOVA), whereas *P. peregrinus* was found from dry eucalypt woodland to rainforest. Although this species appeared to reach its greatest abundance on the wet forest/rainforest ecotone (Fig. 2d), high variance in the rainforest ecotone may have masked any differences in detection rate across the gradient ($P = 0.15$, Kruskal-Wallis Nonparametric ANOVA; Fig. 2d). Three other arboreal mammals (*P. breviceps*, *T. caninus* and *T. vulpecula*) were each seen only once during this part of the study (all near the wet forest/rainforest ecotone), so we were unable to determine their local habitat associations across the gradient.

The small mammal community in wet open-forest

Elliot trapping in the wet open eucalypt forest yielded a sub-set of the small mammals detected in sites T1–T4, although cage traps captured some species not detected at those sites. Our Elliot traps mostly captured *Rattus fuscipes* (148 captures; 43 individuals), *Antechinus stuartii* (107 captures; 21 individuals) and *Melomys cervinipes* (68 captures; 24 individuals), with relatively fewer captures of *R. lutreolus* (7 captures; 2 individuals). For these four species combined, the capture success of small mammals on our two grids was about 16.7% (Table 2). During any one field trip, the minimum numbers of individual animals known-to-be-alive (KTBA) on each 2.6-ha grid averaged about 10 *R. fuscipes*, 8 *A. stuartii*, 5 *M. cervinipes* and <1 *R. lutreolus*. Cage traps captured *Trichosurus caninus* (21 captures; 6 individuals) on both grids, long-nosed bandicoots (*Perameles nasuta;* 4 captures; 3 individuals) on G1 and a single capture of a long-nosed potoroo (*Potorous tridactylus*) on G2. Incidental observations made of other mammals on these grids included sugar gliders, common ringtail possums, greater gliders, common brushtail possums, and swamp wallabies.

DISCUSSION

Mammal richness in Gibraltar Range National Park

In a survey of mammals in a 2400-km^2 area in the upper Richmond and Clarence River catchment in north-eastern NSW, Calaby (1966) recorded the presence of 35 non-flying native mammals, noting that, at the time, it represented one of the richest Australian mammal faunas that had been reported for a comparable area. Barnett *et al.* (1976) surveyed the mammal fauna in a 118-km^2 area at Clouds Creek on the eastern edge of the New England Bioregion, recording 27 non-flying native mammals, and again, this area was heralded for its high species richness. The Clouds Creek area was very similar in geographic context to our own, and serves as a useful benchmark for our study at Gibraltar Range National Park (area = 253 km^2) where we recorded 28 native and six introduced species. Based upon information in the BioNet Database (2005), this species list would include at least 36 native mammals if the adjacent Washpool National Park had been included in our survey, making these parks, and those adjacent to them, of great importance in the protection of the regional mammal biodiversity of north-eastern New South Wales. Recently, Jarman and Vernes (in press) summarised the mammals of the New England Bioregion, concluding that there were 43 species of non-flying native mammal still present there. Based upon the data we have gathered, Gibraltar Range National Park accommodates 65% of the bioregional non-flying mammal fauna, and together with Washpool National Park, these reserves accommodate 83% of the bioregional non-flying mammal fauna.

Macropods (kangaroos, wallabies and rat-kangaroos in the families Potoroidae and Macropodidae) are one of the most species rich groups of mammal that we recorded in Gibraltar Range National Park (eight species), and again, this richness is comparable to other studies in the region. Calaby (1966) recorded 11 species of macropod in the Upper Richmond and Clarence catchment, Barnett *et al.* (1976) recorded nine species at Clouds Creek, and Jarman *et al.* (1987) recorded ten species at Wallaby Creek, which is located in the northern headwaters of the Clarence River within the region where Calaby (1966) worked. Jarman and Vernes (in press) noted that 12 species of macropod persist in the New England Bioregion. Interestingly, two of these species, the eastern grey kangaroo (*M. giganteus*) and common wallaroo (*M. robustus*) appear to be absent from Gibraltar Range National Park, despite their being the most common macropods across the largely modified landscape of the New England Tableland.

Density of vegetation at ground level is typically high in most habitats in the park, which would favour the smaller wallabies and restrict the movement of the larger species.

As with previous studies in north-eastern New South Wales, the macropod diversity we recorded can be attributed to the great diversity of habitat types present at Gibraltar Range National Park, within a relatively small area. For example, we recorded pademelons (*Thylogale* spp.) in rainforest, and based on other research in north-eastern New South Wales (Calaby 1966; Barnett *et al.* 1976; Jarman and Phillips 1989) we suspect that *T. thetis* is more likely to occur around the wet sclerophyll/rainforest ecotone, whereas *T. stigmatica* is likely to occur deeper within the rainforest. *P. tridactylus* was detected in wet forest with a dense understorey, and *M. rufogriseus* was detected primarily in the dry open forest. *W. bicolor* is probably the most widespread macropod in the park, and we detected its presence in all non-rainforest habitats.

M. parma inhabits wet eucalypt forest and rainforest margins throughout its distribution, but at Gibraltar Range, it also occurs in drier eucalypt woodland with a heath understorey (Maynes 1977). The presence of *M. parma* in the dry forest habitat is unusual for this species; in a survey of *M. parma* throughout New South Wales, Maynes (1977) noted that the area along Mulligan's Drive was the only dry sclerophyll forest site in their range where he recorded *M. parma* as being resident. He attributed this occurrence to the availability of dense shrubby cover in the forest understorey for shelter that was in close proximity to open grassy areas around swamps where the wallabies could feed.

Although *P. penicillata* has apparently been sighted in the steep, rocky escarpment region at the eastern edge of the park (BioNet Database, 2005), this record appears to unsubstantiated (Clancy 1999) and needs to be verified, as do the few sightings in the BioNet Database (2005) for *A. rufescens* of which at least one may have been a misidentification (Clancy 1999). Both species occur in the adjacent Washpool National Park (BioNet Database 2005). Another three species of macropod (eastern grey kangaroo *M. giganteus*, common wallaroo *M. robustus*, and whiptail wallaby *M. parryi*) also occur in the adjacent Washpool National Park. Thus, the only macropod species that occurs in New England (see Jarman and Vernes in press), but does not occur locally in the Gibraltar Range/Washpool region, is the black-striped wallaby (*M. dorsalis*).

Another species-rich group in the park was the possums and gliders (see Table 2). Of the eight species reported to be present in the park, we recorded seven, with the most common and widespread of these being *P. volans* and *P. peregrinus*. Although we only recorded the small, cryptic feathertail glider (*A. pygmaeus*) once, it is almost certainly widespread and common in the park, despite only a single record of this species in the BioNet Database (2005). However, we could not verify the presence of the yellow-bellied glider (*P. australis*), of which one sighting has been recorded in the park near its northern boundary with Washpool National Park (BioNet Database 2005).

Threatened species in the park

Nine threatened species of mammal are listed as occurring in Gibraltar Range National Park (Table 2). In particular, the park is reputed to have a large population of *D. maculatus* (NSW NPWS 2005), and together with Washpool and Barool National Parks, contains a significant percentage of the state population of *M. parma* (NSW NPWS 2005). Other macropods of conservation interest in the park include *T. stigmatica* and *P. tridactylus*, and, if records are substantiated, *A. rufescens* and *P. penicillata*.

Mammal community dynamics

The diversity of habitats within a relatively small area is one of the factors that contribute to the high species richness that we recorded in Gibraltar Range National Park. We tested this by trapping and spotlighting mammals across a steep gradient in vegetation from swamp to rainforest, and found that despite the short distance (~700 m) there were significant and consistent changes in the structure of the mammal community. One suite of species (*R. fuscipes*, *M. cervinipes* and *P. peregrinus*) appeared to have wide habitat tolerances but reached their highest abundances at the ecotone between eucalypt forest and rainforest, whereas another suite of species (*P. novaehollandiae*, *M. musculus* and *R. lutreolus*) favoured the ecotone between swamp and the dry, heath-dominated eucalypt woodland. Although we had fewer captures of eastern pygmy possums (*Cercartetus nanus*), our data point towards this species favouring the intermediate vegetation types along the gradient (wet and dry eucalypt forest and woodland), particularly the ecotone between the two. These are the floristically more diverse habitats along our habitat gradient in terms of flowering heath plants such as banksias (*Banksia* spp.) and bottlebrushes (*Callistemon* spp.) (Howes 2004), and they are therefore likely to support the highest numbers of this primarily nectar-feeding marsupial (Ward 1990). *A. stuartii* occurred across much of the gradient and appeared to be the only habitat generalist that we

detected. *P. volans* was widespread within the open forest habitat across the entire gradient, but reached highest densities in the wet eucalypt forest, an observation that is consistent with other studies (e.g. see Bennett *et al.* 1991). Although too few sightings were made of brushtail possums (*Trichosurus* spp.) during this part of the study, previous work on *T. caninus* indicated that it is a rainforest/wet forest specialist (How 1972). We saw this species during our various spotlighting surveys throughout the park only in the rainforest and its wet eucalypt forest ecotone, whereas *T. vulpecula* is a species of more open forest (How 1972) and we saw it in low numbers in the wet open eucalypt forest.

Williams and Marsh (1998) studied ground-dwelling mammals across a rainforest/open-forest ecotone in north Queensland, and our observations from Gibraltar Range are consistent with their work, despite some differences in the way individual species responded. They noted significant changes to the mammal community across their vegetation gradient, with some species being more generalist in habitat preference (e.g. *R. fuscipes* and *M. cervinipes*), whereas others were strictly associated with rainforest (e.g. *A. stuartii*) or open forest (e.g. *R. lutreolus*).

On our intensively sampled grids in wet open eucalypt forest, *R. fuscipes* and *A. stuartii* were the most dominant species in terms of animals known-to-be-alive (KTBA), followed by *M. cervinipes*. By comparison, *R. lutreolus* was considerably less common. Population sizes of other species were more difficult to discern, mainly because these animals are harder to trap using conventional techniques. As a continuation of this study, we will trial a range of methods for the capture of some of the larger mammals, including bandicoots, potoroos, possums and wallabies.

Summary and conclusions

The data we gathered on habitat associations of mammals from trapping grids and transects, and spotlighting transects throughout this study, as well as other direct and indirect observations of mammals within the park, yielded a total of 28 species of non-flying native mammals. The most species-rich habitats in the park appear to be the wet eucalypt forests and the dry open eucalypt woodland with a heath understorey (Fig. 3). Importantly though, rainforest, swamps and rocky outcrops accommodate species not found in these dominant habitat types, and the overall habitat complexity at Gibraltar Range serves to generate its high species richness. Although the richness of mammals in Gibraltar Range is high by regional standards, we feel that some records of mammals in the park that were not gathered by us require further validation (e.g. *P. penicillata, A. rufescens, P. australis*), and we plan to target these species as part of our future work. Furthermore, there are species in the national parks adjacent to Gibraltar Range that have not been recorded in the park (such as the brush-tailed Phascogale *Phascogale tapoatafa* and the common dunnart *Sminthopsis murina*), despite suitable habitat probably being present. Thus, our continuing work will also aim to provide a definitive and comprehensive list of mammal species in time.

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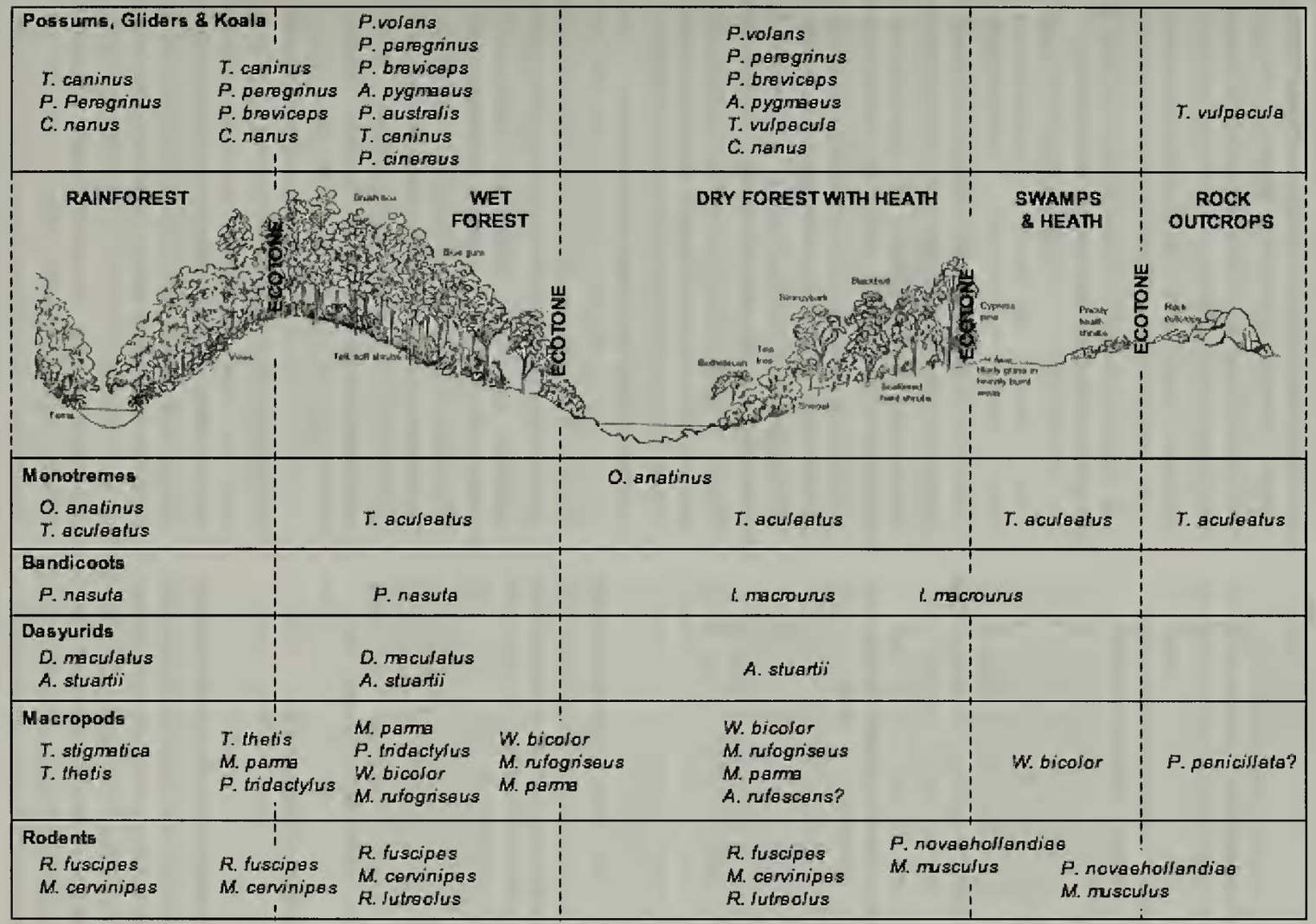

Figure 3. Schematic representation of the broad mammal communities and their vegetation associations at Gibraltar Range National Park based upon the data we have gathered. The vegetation types depicted in this figure has been used and modified, with permission from NPWS, Glen Innes.

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